COLUMBUS STAINLESS [Pty] Ltd

Technical Brochure

Cr-Ni-Mo AUSTENITIC STAINLESS STEELS

Adding Stainless Quality to life

www.columbusstainless.co.za

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Introduction

The Cr-Ni-Mo austenitics are molybdenum bearing austenitic stainless steels having very good corrosion resistance in many aggressive environments.

The molybdenum addition ensures more resistance to pitting and crevice corrosion in chloride containing media, sea water and chemical environments such as sulphuric acid compounds, phosphoric and acetic acids.

The lower rate of general corrosion in mildly corrosive environments gives the steel good atmospheric corrosion resistance in polluted marine atmospheres. As they are austenitic, they have excellent ductility, formability and toughness even at sub-zero temperatures.

316L-1.4404 has a low carbon content to minimise the problem of carbide precipitation during welding and permits the use of the steel in the as-welded condition in a wide variety of corrosive applications.

This grade also complies to the requirements of 1.4402 which has been specifically designed for use in tank containers and has enhanced mechanical properties to aid in tank container design.

316L-1.4435 has a higher molybdenum content than U-316L-1.4404 and this improves the pitting and crevice corrosion resistance even further.

316LN has a higher nitrogen content to improve the strength.

316Ti is a titanium stabilised version of 316L-1.4404 and is used for its resistance to sensitisation during prolonged exposure to temperatures between 550°C and 800°C.

Product range

The latest revision of the Product Catalogue should be consulted, as the product range is subject to change without notice.
The Product Catalogue is available from the Technical Department or can be found at www.columbusstainless.co.za

Specifications and tolerances

Columbus Stainless (Pty) Ltd supplies the Cr-Ni-Mo austenitics to the ASTM A240, ASME SA240, EN 10088-2 and EN 10028-7.Columbus Stainless (Pty) Ltd normally supplies material to the following tolerances:

HOT ROLLED

ASTM A480M
ISO 9444 - material processed as coil
ISO 18286 - material processed as plate
ASTM A480/ASTM A480M
ASME ASME SA480/ASME SA480M

ISO 18286
ISO 9444-2
EN 10051
EN 10029
IS 6911

COLD ROLLED

ASTM A480M
ISO 9445
ASTM A480/ASTM A480M
ASME SA480/ASME SA480M
ISO 9445-2
IS 6911

Other specifications and tolerances may be available on request. Further information is available in the Product Catalogue, which can be obtained from the Technical Department or can be found at www.columbusstainless.co.za

Further information

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Disclaimer

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Chemical composition

In accordance with ASTM A240 and EN 10088-2.

Grade	C	Si	Mn	P	S	N	Cr	Mo	Ni	Others
316L-1.4404	0.03	0.75	2.0	0.045	0.015	0.10	16.5 18.0	2.0 2.5	10.0 13.0	
316L-1.4435	0.03	0.75	2.0	0.045	0.015	0.10	17.0 18.0	2.5 3.0	12.5 13.0	
316LN	0.03	0.75	2.0	0.045	0.015	0.12 0.16	16.5 18.0	2.0 2.5	10.5 13.5	
316Ti	0.08	0.75	2.0	0.045	0.015	0.10	17.0 19.0	2.0 2.5	10.5 13.5	Ti: 5x(C+N) 0.7

- Compositions are ranges or maximum values.

Mechanical properties

In accordance with ASTM A240 and EN 10088-2.

Grade	R_m (MPa)	$Rp_{0.2}$ (MPa)	$Rp_{1.0}$ (MPa)	El (%)	Max BHN
316L-1.4404	530 to 680 (≤8mm) 520 to 670 (>8mm)	240 (CR) 220 (HR)	270 (CR) 260 (HR)	40 (≤8mm) 45 (>8mm)	217
316L-1.4435	550 to 700 (≤8mm) 520 to 670 (>8mm)	240 (CR) 220 (HR)	270 (CR) 260 (HR)	40 (≤8mm) 45 (>8mm)	217
316LN	580 to 780	300 (CR) 280 (HR)	330 (CR) 320 (HR)	40	217
316Ti	540 to 690 (≤8mm) 520 to 670 (>8mm)	240 (CR) 220 (HR)	270 (CR) 260 (HR)	40	217

- Minimum values, unless max or range is indicated.
- ( ) indicates applicable gauge range.
- HR is hot rolled, CR is cold rolled.
- The table assumes certification to both ASTM A240 and EN 10088-2.

PROPERTIES AT ELEVATED TEMPERATURES

The properties quoted below are typical of annealed 316L and 316Ti type steels. These values are given as a guideline only, and should not be used for design purposes.

Short time elevated temperature tensile strength (MPa)

Grade	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1 000°C	1 000°C
316L types	490	480	460	440	420	395	305	180	70	30	15
316Ti	535	540	530	510	505	480	395	275	150	75	20

Short time elevated temperature 0.2% proof stress (MPa)

Grade	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C
316L types	215	170	150	135	130	120	115	100
316Ti	225	220	190	165	160	155	150	145

Short time elevated temperature elongation (%)

Grade	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1 000°C	1 000°C
316L types	52	51	48	47	45	47	49	55	61	66	71
316Ti	52	50	47	47	49	56	62	70	72	71	69

Maximum recommended service temperature

Continuous (°C)	Intermittent (°C)
920	870

- In oxidising conditions

PROPERTIES AT ELEVATED TEMPERATURES (CONTINUED)

Creep and creep rupture properties

	Stress (MPa) to produce 1% strain		Stress (MPa) to produce rupture	
Temperature (°C)	10 000 hours	100 000 hours	1 000 hours	10 000 hours
550	225	125	320	270
600	145	80	220	170
650	95	55	160	110
700	65	35	110	70
750	40	20	75	45
800	30	15	55	30
850	20	10	35	20

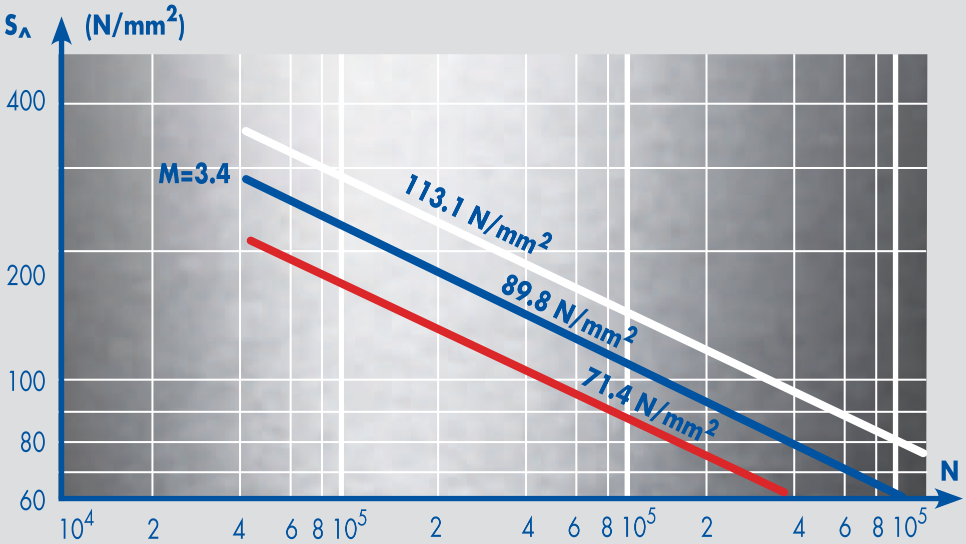
FATUGUE CONSIDERATION

When looking into the fatigue of austenitic stainless steels, it is important to note that design and fabrication - not material, are the major contributors to fatigue failure. Design codes (e.g. ASME and BS 5500) use data from low-cycle fatigue tests carried out on machined specimens to produce conservative S-N curves used with stress concentration factors (k_1c) or fatigue strength reduction factors (k_f).

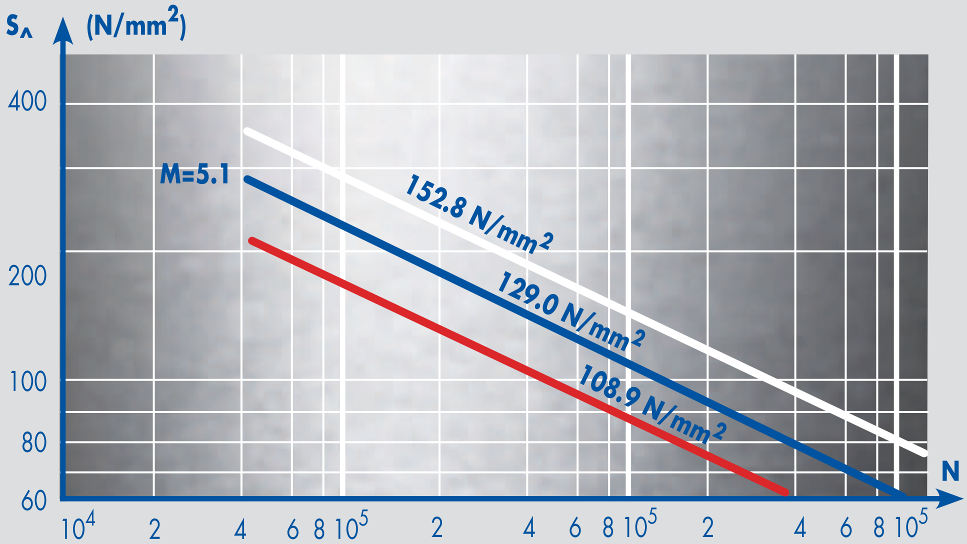
In essence, the fatigue strength of a welded joint should be used for design purposes, as the inevitable flaws (even only those of cross-sectional change) within a weld will control the overall fatigue performance of the structure.

The curves show results of welded joints under variable loading for austenitic stainless steel U-316Ti following Eurocode 3. When compared with the literature, the fatigue properties of U-316Ti appear to be similar to those of mild steel.

Fatigue strength of stainless steel specimens with longitudinal rib



Fatigue strength of stainless steel specimens with transverse rib



• Survival probabilities • 1 - 2.5% • 2 - 50% • 3 - 97.5% • Ref Eurocode 3.

Physical properties

The values given below are for 20°C, unless otherwise stated.

Density (kg/m^3)		8 000
Modulus of elasticity in tension (GPa)		193
Modulus of elasticity in torsion (GPa)		70
Specific heat Capacity (J/kg K)		500
Thermal conductivity at	100°C (W/m K)	16.2
	500°C (W/m K)	21.5
Electrical resistivity (x10^{-9} Ω m)		740
Mean coefficient of thermal expansion from	0 to 100°C (x10^{-6} K^{-1})	15.9
	0 to 300°C (x10^{-6} K^{-1})	16.2
	0 to 500°C (x10^{-6} K^{-1})	17.5
	0 to 700°C (x10^{-6} K^{-1})	18.5
Melting range (°C)		1 390
		1 430
Relative permeability		1.02

Thermal processing and fabrication

ANNEALING

Annealing of the Cr-Ni-Mo austenitics is achieved by heating to between 1 010°C and 1 120°C for 60 minutes per 25mm thickness (2.5min/mm) followed by water or air quenching. The best corrosion resistance is achieved when the final annealing temperature is above 1 070°C 316Ti should not be annealed above 1 060°C. Controlled atmospheres are recommended in order to avoid excessive oxidation of the surface.

STRESS RELIEVING

The Cr-Ni-Mo austenitics can be stress relieved at 450°C to 600°C for 45 minutes per 25mm thickness (1.5min/mm) with little danger of sensitisation. A lower stress relieving temperature of 400°C maximum must be used with316LN with longer soaking times.

HOT WORKING

The Cr-Ni-Mo austenitics can be readily forged, upset and hot headed. Uniform heating of the steel in the range of 1 150°C to 1 250°C is required. The finishing temperature should not be below 900°C. Upsetting operations and forgings require a finishing temperature between 930°C and 980°C. Forgings should be air cooled. All hot working operations should be followed by annealing and pickling and passivation to restore the mechanical properties and corrosion resistance.

COLD WORKING

The Cr-Ni-Mo austenitics are extremely tough and ductile and can thus be readily deep drawn, stamped, headed and upset without difficulty. Since austenitic stainless steels work harden, severe cold forming operations should be followed by annealing.

MACHINING

Like all the austenitic stainless steels, this alloy group machines with a rough and stringy swarf. Rigidly supported tools with as heavy a cut as possible should be used to prevent glazing.

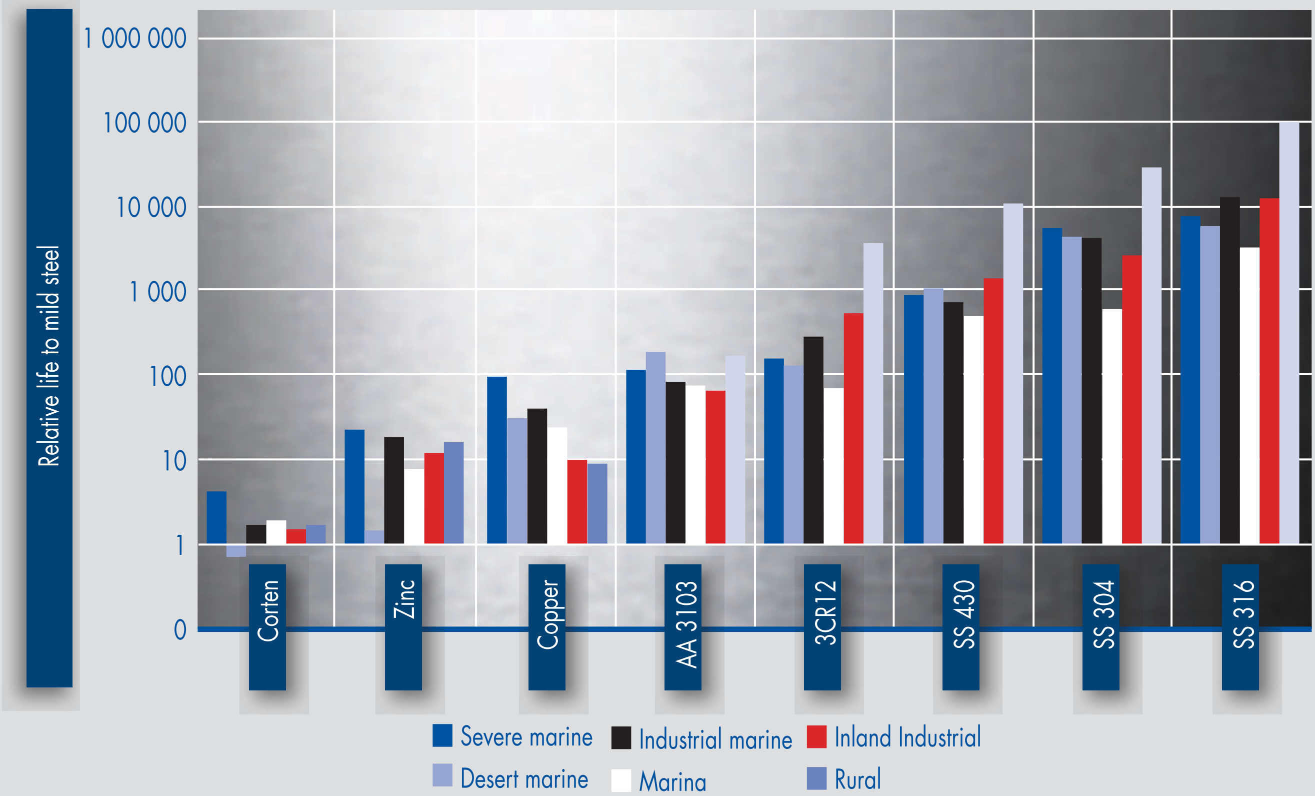
WELDING

The Cr-Ni-Mo austenitics have good welding characteristics and are suited to all standard welding methods. Either matching or slightly over-alloyed filler wires (e.g. ERW 309Mo) should be used. For maximum corrosion resistance, the higher nitrogen type 316LN should be annealed after welding to dissolve any chromium nitrides which may have precipitated. The weld discolouration should be removed by pickling and passivation to restore maximum corrosion resistance.

Corrosion resistance

The above diagram summarises the corrosion (pitting) resistance of the austenitic and duplex stainless steels produced at Columbus. This would indicate that the corrosion resistance of the Cr-Ni-Mo austenitic types are all similar and suitable for marine environment applications.

ATMOSPHERIC CORROSION



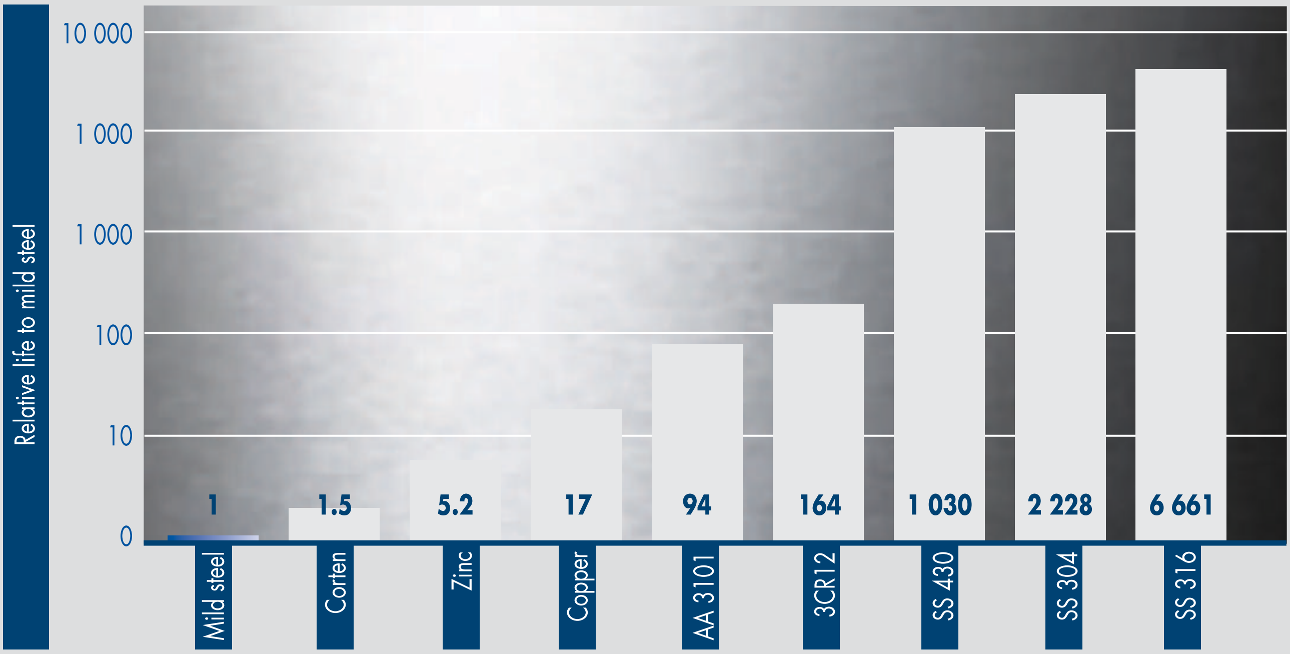
The atmospheric corrosion resistance of austenitic stainless steel is unequalled by virtually all other uncoated engineering materials. Stainless steel develops maximum resistance to staining and pitting with the addition of molybdenum. For this reason, it is common practice to use the Cr-Ni-Mo austenitics grades in areas where the atmosphere is highly polluted with chlorides, sulphur compounds and solids, either singly or in combination. However, in urban and rural areas the Cr-(Mn)-Ni austenitics generally perform satisfactorily.

From the report 'Atmospheric Corrosion Testing in Southern Africa - Results of a Twenty Year Exposure Programme' by BG Callaghan, Division of Materials Science and Technology, CSIR, the adjacent graphs can be constructed.

ATMOSPHERIC CORROSION (CONTINUED)

These graphs show the relative life of eight metals compared to mild steel in six different atmospheric environments. The graph can be summarised to give an average relative life of the different metals in atmospheric conditions.

In appearance, all the metals showed discolouration at the more severe sites after 20 years. None of the metals were washed during the exposure programme and this clearly emphasises the importance of keeping stainless steel clean and that stainless steel is a LOW maintenance (not NO maintenance) option in atmospheric corrosion applications.

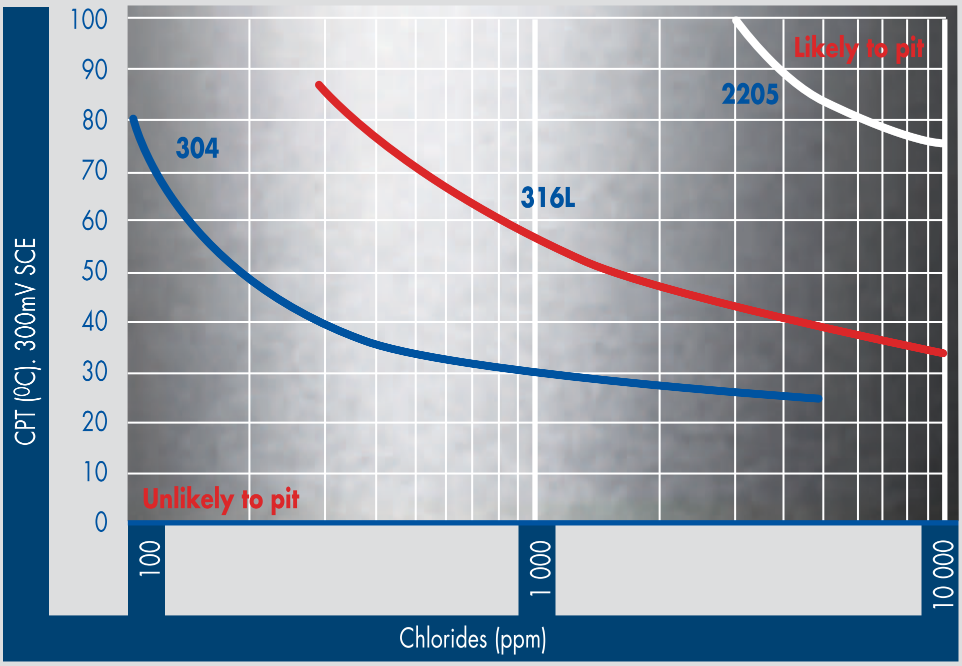


GENERAL CORROSION

The Cr-Ni-Mo austenitics have superior corrosion resistance to the Cr-(Mn)-Ni austenitics. They have good resistance to most complex sulphur compounds such as those found in the pulp and paper industry and they have good resistance to pitting in phosphoric and acetic acids.

PITTING CORROSION

Pitting resistance is important, mainly in applications involving contact with chloride solutions, particularly in the presence of oxidising media. These conditions may be conducive to localised penetration of the passive surface film on the steel and a single deep pit may well be more damaging than a much greater number of relatively shallow pits. Where pitting corrosion is anticipated, steels containing molybdenum (such as the Cr-Ni-Mo austenitics) should be considered. The adjacent diagram shows the critical temperature for initiation of pitting (CPT) at different chloride contents for 304,316L and 2205 types (potentiostatic determination at + 300mV SCE, pH = 6.0).



OXIDATION RESISTANCE

Cr-Ni-Mo austenitics have good oxidation resistance in intermittent service up to 870°C and in continuous service to 920°C.

INTERGRANULAR CORROSION

Sensitisation may occur when the Heat Affected Zones of welds in some austenitic stainless steels are cooled through the sensitising temperature range of between 450°C and 850°C. At this temperature, a compositional change may occur at the grain boundaries. If a sensitised material is then subjected to a corrosive environment, intergranular attack may be experienced. This corrosion takes place preferentially in the heat affected zone away from and parallel to the weld. Susceptibility to this form of attack, often termed 'weld decay', may be assessed by the following standard tests:

a) boiling copper sulphate/sulphuric acid test as specified in ASTM A262, Practice E.

b) for non titanium stabilised grades only, boiling nitric acid test as specified in ASTM A262, Practice C.

The Columbus Stainless Cr-Ni-Mo austenitics have low carbon contents and are resistant to sensitisation and can be specified for welded structures unless the higher carbon types are required for their increased strength at elevated temperatures. In this case, 316Ti should be specified

STRESS CORROSION CRACKING

Stress corrosion cracking (SCC) can occur in austenitic stainless steels when they are stressed in tension in chloride environments at temperatures in excess of about 60°C. The stress may be applied, as in a pressure system or it may be residual arising from cold working operations or welding.

Additionally, the chloride ion concentration need not be very high initially, if locations exist in which concentrations of salt can accumulate. Assessment of these parameters and accurate prediction of the probability of SCC occurring in service is therefore difficult. Where there is a likelihood of SCC occurring, a beneficial increase in life can be easily obtained by a reduction in operating stress and temperature. Alternatively, specially designed alloys, such as duplex stainless steels, will have to be used where SCC cracking is likely to occur.

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